DRAFT

Development and analysis of a Target Fish Community model to assess the biological integrity of the Designated Reach of the Lamprey River, New Hampshire, and identify indicator fish species for a MesoHABSIM model

Introduction

Target Fish Community (TFC) models have been utilized within instream flow related studies on multiple rivers in Southern New England since Bain and Meixler's initial development and application of the methodology on the Quinebaug River (2000). Successful applications of the approach to assess the status of native fish communities on the Quinebaug, Ipswich, Assabet, Charles, Housatonic, Souhegan, and Pomperaug Rivers (Bain and Meixler 2000, Armstrong et al. 2001, Parker et al. 2004, Meixler 2005, Kearns et al. 2005, Legros 2006a, Legros 2006b) have demonstrated the effectiveness of TFC models as fish community assessment tools. These practical applications illustrate the ability of TFC models to assess the biological integrity of streams using an inference approach based on the biological requirements of fish species (or species groups) and a comparison of their compositions within a TFC and the exiting fish community of a study stream (or stream segment). The increasing use and acceptance of this methodology, and similar methods, are indicative of the recognized importance of using fish communities to assess the biological integrity of aquatic systems (Karr 1981, Fausch et al. 1990, Hughes 1995, Halliwell et al. 1999).

As part of an on-going Protected Instream Flow Study, the Northeast Instream Habitat Program (NEIHP), in an effort to identify and define the flow dependency of the native fish fauna within the Designated Reach of the Lamprey River, conducted an assessment of fish habitat that included the delineation of hydro-morphological units (HMU), and measurement of water depths and velocities at multiple flow conditions. A habitat simulation model, MesoHABSIM (Parasiewicz 2001), will be used to determine the relationship between flow conditions and instream habitat availability for selected fish species based on that assessment. The analysis will entail the use multivariate

statistics to determine physical habitat characteristics associated with habitat suitability for individual fish species (or species groups) to determine suitable habitat areas and will assess changes in fish habitat availability with regard to changes in stream flow conditions. As a component of this project, a TFC model was created to identify the native fluvial fish species that will be considered indicators for the MesoHABSIM modeling process and assess the biological integrity of the Lamprey River. Assessment of the biological integrity was based on a comparative evaluation of the composition of species (or species groups) within the exiting fish community to those of the TFC.

Development of the TFC was dependent upon the use of fish data from several ecologically healthy Reference River sites that are geomorphically and zoogeographically[1] similar to the Lamprey River study area. Defining the model was an interactive process that required direct input from local fisheries experts to assure that the species compositions of the proposed fish community model were conducive to watershed management objectives and consistent with the fish fauna of the Lamprey River study area. Reference River fisheries data used to calculate the TFC model were provided by various agencies and organizations.

The development and analysis processes consisted of multiple steps: First, a list of species expected or with the potential to occur within the study area was compiled. Next, a group of rivers (or sections of rivers) having geomorphic and zoogeographic characteristics similar to those of the Lamprey River study area were selected as potential references using a simple Geographic Information System (GIS) geoprocessing model. This list of rivers was then filtered based on ecological condition, habitat quality, and the availability of fish collection data to remove those possessing impacted conditions or lacking adequate fish data. The remaining rivers were considered the best available Reference Rivers for the Lamprey River study area. Then, existing fish collection data from these Reference Rivers were subjected to a weighted-ranking procedure to calculate the composition and proportions of fish species within the TFC (Bain and Meixler 2000). Finally, the TFC model was compared to recent fish data collected within the Lamprey River to assess the current condition of the existing fish community.

[1] Determination of the zoogeographic similarity of areas, or Ecoregions, is based on an analysis of geology, physiography, vegetation, climate, soils, land use, wildlife and hydrology (Omernik 1987).

This report presents the Target Fish Community model developed for the Lamprey River. The development and calculation processes are described in detail, the resulting community is given, and a comparative analysis identifying deviations between the expected (TFC) and existing fish community assemblages is illustrated and explained. Potential reasons for such deviations, related to biological integrity, are then suggested using an inference approach based on the compositions of fish species within the communities with regard to habitat use and pollution and thermal regime tolerances. The indicator fish species selected for training of the MesoHABSIM model developed for the Lamprey River Protected Instream Flow Study are also identified from the TFC.

Methods

Study Area – Designated Reach

The Lamprey River is a low gradient, low elevation, and fourth order, coastal stream which flows 45.3 miles from the town of Northwood to New Market, where it enters the Western side of Great Bay, and drains 212 square miles of the State of New Hampshire's Coastal Watershed. The National Park Service designated the 11.5 mile segment of the Lamprey River between Bunker Pond (Epping) and the confluence of with the Piscassic River (near the Durham-Newmarket town line) as a Wild and Scenic River in 1996. This segment of the Lamprey River (hereafter referred to as the Designated Reach) is the focus area for a Protected Instream Flow Study commissioned by the New Hampshire Department of Environmental Services (NHDES). The TFC described here has been developed to represent the expected fish community of this area based on the geomorphic and zoogeographic characteristics of the stream within the Designated Reach. Consequently, the TFC is not applicable as a reference for the expected fish communities of segments of the Lamprey River outside of the Designated Reach.

Fish List

A comprehensive list of fish species with known current or historic distributions, or with potential to occur within the Designated Reach was compiled using distribution references, and historic and recent observations and survey collection records (Jackson 1922, NHFGD 1983-5, Schmidt 1986, Scarola 1987, NHDES 2005, TNC 2006). All species within this list were assigned habitat use classifications based on information compiled by Bain (2000) using regional and state ichthyology books (Scott and Crossman 1973, Pflieger 1975, Lee et al. 1980, Trautman 1981, Becker 1983, Burr and Warren 1986, Robinson and Buchanan 1988, Jenkins and Burkhead 1994). Species were classified as fluvial specialists, fluvial dependents, or macrohabitat generalists based on macrohabitat (water body-type) use requirements. Brook trout, creek chub, fallfish, and longnose dace were reclassified from macrohabitat generalists to fluvial specialists in this study, as in previous target fish community studies within this region, based on their local habitat use patterns (Lang et al., 2001; Kearns et al., 2005). American eel was classified as a macrohabitat generalist/fluvial dependent. While this species is a habitat generalist, it is dependent upon fluvial conditions to access the sea to spawn and return to freshwater as a juvenile to live and mature. Pollution tolerance classifications were assigned based on the tolerance classifications of the U.S. Environmental Protection agency and Halliwell et al. (1999). Species were classified as intolerant (I), moderately tolerant (M), or tolerant (T). Thermal regime classifications were also assigned based on temperature tolerances. Fish were classified as cold-water, eurythermal*, or warm-water species (Lyons 1996, Halliwell et al. 1999, and Langdon 2001). Finally, species were classified as native or introduced (exotic) based on regional and local distribution accounts (Schmidt 1986, Scarola 1987).

Reference River Selection

In order to develop a TFC that was representative of the fish community one would expect within the Designated Reach under given an un-impacted situation it was necessary to establish reference conditions. Once these reference conditions were

* Species tolerating a broad range of temperature from cold to warm

established, rivers that possessed geomorphic and zoogeographic characteristics similar to those of the Designated Reach, and in were found to be in good ecological health could be selected as Reference Rivers. Fish data from these rivers could then be used to develop the Lamprey TFC.

Establishment of reference conditions and initial selection of potential Reference Rivers were accomplished using ArcMap (ESRI, Inc., 1999-2004) GIS software tools. Within Arc GIS, the "Model Builder" tool was used to create a model that would select rivers similar to the study river. A query was developed within model builder to select rivers, based on five defined geomorphic attributes and their parameters (square miles of drainage area, stream order, gradient class, elevation class, and percent of calcareous geologic formations). The quantitative parameters of these attributes were set to match those of the Designated Reach and the query was applied to The Nature Conservancy's (TNC) "stream classification data layer" within Arc GIS. Once applied, the model selected those rivers meeting the parameters of the five defined geomorphic attributes using the "selection" tool within model builder creating a new GIS layer containing only those rivers that were geomorphically similar to the Lamprey River Designated Reach.

Next, this group of potential reference rivers was narrowed based on zoogeographic location, or ecoregion. By projecting a map of Level III ecoregions (Omernik 1987) with the TNC rivers data layer, it was determined that the Designated Reach of the Lamprey River was within Ecoregion 59, the Northeastern Coastal Zone. In order to eliminate the geomorphically similar rivers that were located outside of this ecoregion, the Reference River Selection Model (RRSM) was automated to clip the rivers that were within the same Level III Ecoregion using the "clip" function within GIS. The result was a new GIS layer containing only those rivers that were both geomorphically and zoogeographically similar to the Designated Reach. The resulting Reference River Selection Model (RRSM) is capable of automatically selecting potential Reference Rivers for a selected stream (or stream segment) based on the actual physical conditions and regional location of the stream or its overall similarity to the study stream. The importance of this is critical to the TFC development process considering the relationships between stream geomorphology/zoogeography and fish community compositions.

The ecological condition of these rivers is then assessed to determine their overall suitability as Reference Rivers using the definition of Kearns et al. (2005)[2]. Rivers that were deemed to be in poor ecological condition were eliminated from consideration. The list of potential rivers was further filtered based on the availability of fish data. The remaining rivers, containing adequate fish data and possessing high ecological integrity were designated as Reference Rivers. Fish data from these rivers were then compiled and utilized for the calculation of the TFC model.

Target Fish Community Development

The New Hampshire Department of Environmental Services (NHDES) and Fish and Game Department (NHFGD), Northeast Instream Habitat Program (NEIHP), Massachusetts Division of Fisheries and Wildlife (MADFW), Connecticut Department of Environmental Protection (CTDEP), and Rhode Island Department of Environmental Management (RIDEM) provided the fisheries data used to calculate the model and were instrumental in the development process. Geographic coordinates of the fish-data sample sites were superimposed over the selected portions of the Reference Rivers using GIS software to determine the exact locations of sample sites. Fish data that did not originate from within a selected suitable section of a Reference River were not considered in the development of the TFC model.

Following the methods of Bain and Meixler (2000), the total number of fish at each site was summed. The totals of each species were divided by this sum, yielding a proportion of the total catch. These proportions were summed for all sites. The sums of the proportions were then ranked, with the species having the greatest sum ranked "1". At this point all non-native species were removed from the calculation. Although these species were removed, all of the species remaining on the list maintained the same numerical rank. Then, the reciprocal of each species' rank was taken, and these reciprocals were summed. The reciprocal rank of any given species divided by the sum of the reciprocal ranks yielded that species' expected proportion in the Lamprey River TFC. All of these calculations were done on a spreadsheet created by Mark Bain (2000).

[2] In a similar analysis on the Housatonic River (Kearns et al. 2004), quality rivers were defined as being "relatively unimpaired, undammed, and undeveloped with few water withdrawals, good water quality, and a similar temperature regime."

Lamprey River Existing Fish Community

Comprehensive sampling data collected during the Lamprey River Baseline Fish Sampling Survey between August 25 and August 29, 2003 was used to define the existing fish community of the Lamprey River Designated Reach. Fish collections were conducted at 43 stations using gill nets, shoreline seining, and backpack, barge, and boat-mounted electrofishing methods. The Lamprey River Baseline Fish Community survey was designed and implemented to collect a complete, representative sample of resident fish species within the Designated Reach which took into account the distribution of available macrohabitat types. This unique and comprehensive study design served to strengthen the legitimacy of an evaluation of the existing fish community using the TFC approach. There is a high degree of likelihood that the vast majority of species present within the Designated Reach were sampled during this study allowing for an accurate and complete comparison with the TFC.

Fish Community Evaluation

An evaluation of the current condition of the existing fish community of the Lamprey River was accomplished by comparing the similarity between the TFC and the existing fish community. To make this comparison, we used the percent model affinity procedure developed by Novak and Bode (1992). This procedure yields values from 0 to 100 to describe the extent to which the study river's fish community is similar to the TFC. Higher percent model affinity values indicate higher degrees of similarity between the communities. These values are calculated as:

$$\text{Percentage similarity} = 100 - 0.5 \sum \left| \textit{expected}\ \% - \textit{observed}\ \% \right|$$

where *expected* % is the percentage of individuals of a particular species in the TFC and *observed* % is the percentage of the same species in the existing fish community.

Additional similarity comparisons were also made between the two communities based on the expected and existing proportions of habitat use, pollution tolerance, and

thermal regime tolerance classification guilds using the percent model affinity approach. For example, the absolute differences between percentages of the habitat use classification guilds (e.g. fluvial specialists, fluvial dependent, macrohabitat generalist) of the communities were summed, multiplied by 0.5, and subtracted from 100 to determine the percentage similarity between the two communities based habitat use classes.

A percent deviation calculation was then conducted for each individual species and for each individual species-group guild to quantify deviations between expected (TFC) and existing community compositions:

$$\text{Percent deviation} = | \textit{expected}\ \% - \textit{observed}\ \% \ | \ / \textit{expected}\ \%$$

Percent deviation was calculated for each species to quantify deviations from expected proportions and document under-represented species, over-represented species and species found in proportions similar to expected proportions. Species with proportions deviating by more than 50% less or greater than expected (TFC) proportions were considered under-represented or overly abundant, respectively. Native species identified in the TFC that were missing from the existing fish community, or *vice versa*, and non-native species occurring within the existing community were also identified. Similarly this was conducted for each of the classes within the species-group guilds to quantify deviations at the species-group level.

Results

Fish List

Based on our review of fish distribution references, historical records, and recent collection records, 37 different fish species, from 13 families, were found to occur either historically or currently within the Lamprey River study area (**Table 1**). The list contains a variety of species, both native and introduced, with a full range of habitat use, pollution tolerance, and thermal regime classifications.

Table 1. Expected fish species of the Lamprey River Designated Reach.
Native (N) or introduced (I) statuses, fluvial specialist (FS), fluvial dependent (FD), or macrohabitat generalist (MG) habitat use classifications, intolerant (I), moderately tolerant (M), or tolerant (T) pollution tolerances, and Cold, Eurythermal, or Warm water thermal regime tolerances are given for each species.

FAMILY Common name	*Genus*	*Species*	Native or Introduced	Habitat use classification	Pollution tolerance	Thermal regime
Petromyzontidae						
Sea lamprey	*Petromyzon*	*marinus*	N	FD	M	Eurythermal
Anguillidae						
American eel	*Anguilla*	*rostrata*	N	MG/FD*	T	Eurythermal
Clupeidae						
Blueback herring	*Alosa*	*aestivalis*	N	FD	M	Warm
Alewife	*Alosa*	*pseudoherangus*	N	FD	M	Eurythermal
American shad	*Alosa*	*sapidissima*	N	FD	M	Warm
Salmonidae						
Rainbow trout	*Oncorhynchus*	*mykiss*	I	FD	I	Cold
Atlantic salmon	*Salmo*	*salar*	N	FS	I	Cold
Brown trout	*Salmo*	*trutta*	I	FD	I	Cold
Brook trout (char)	*Salvelinus*	*fontinalis*	N	FS	I	Cold
Osmeridae						
Rainbow smelt	*Osmerus*	*mordax*	N	FD	M	Cold
Escocidae						
Redfin pickerel	*Esox*	*americanus*	N	MG	M	Warm
Chain pickerel	*Esox*	*niger*	N	MG	M	Warm
Cyprinidae						
Common shiner	*Luxilus*	*cornutus*	N	FD	M	Eurythermal
Golden shiner	*Notemigonus*	*crysoleucas*	N	MG	T	Eurythermal
Bridle shiner	*Notropis*	*bifrenatus*	N	MG	I	Warm
Spottail shiner	*Notropis*	*hudsonius*	I	MG	M	Eurythermal
Blacknose dace	*Rhinichthys*	*atratulus*	N	FS	T	Eurythermal
Longnose dace	*Rhinichthys*	*cataractae*	N	FS	M	Eurythermal
Creek chub	*Semotilus*	*atromaculatus*	N	FS	T	Eurythermal
Fallfish	*Semotilus*	*corporalis*	N	FS	M	Eurythermal
Catostomidae						
Common white sucker	*Catostomus*	*commersoni*	N	FD	T	Eurythermal
Creek chubsucker	*Erimyzon*	*oblongus*	N	FS	I	Eurythermal
Ictaluridae						
Yellow bullhead	*Ameiurus*	*natalis*	I	MG	T	Warm
Brown bullhead	*Ameiurus*	*nebulosus*	N	MG	T	Warm
Cyprinodontidae						
Banded killifish	*Fundulus*	*diaphanus*	N	MG	T	Warm
Moronidae						
White perch	*Morone*	*americana*	N	MG	M	Eurythermal
Striped bass	*Morone*	*saxitilis*	N	FD	M	Warm
Centrarchidae						
Rock bass	*Amblopites*	*rupestris*	I	MG	M	Eurythermal
Banded sunfish	*Enneacanthus*	*obesus*	N	MG	M	Warm
Redbreast sunfish	*Lepomis*	*auritus*	N	MG	M	Warm
Pumpkinseed	*Lepomis*	*gibbosus*	N	MG	M	Warm
Bluegill	*Lepomis*	*macrochirus*	I	MG	T	Warm
Smallmouth bass	*Micropterus*	*dolomieu*	I	MG	M	Eurythermal
Largemouth bass	*Micropterus*	*salmoides*	I	MG	M	Warm
Black crappie	*Pomoxis*	*nigromaculatus*	I	MG	M	Warm
Percidae						
Swamp darter	*Etheostoma*	*fusiforme*	N	MG	M	Warm
Yellow perch	*Perca*	*flavescens*	N	MG	M	Eurythermal

*American eel is a diadromous macrohabitat generalist species which requiring fluvial conditions for migration and are classified as macrohabitat generalist/fluvial dependent

Reference Rivers

The Reference Rivers selected for the development of the Lamprey River TFC and a quantitative matrix of their geomorphic and zoogeographic conditions are presented in **Table 2**. The average values of these conditions within the Designated Reach are also given. **Figure 1** is a map illustrating the locations of the selected reference rivers and sample locations of fish data used in the development of the TFC.

Table 2. Selected Reference Rivers and matrix of the geomorphic and zoogeographic parameters defining suitability. Average values of attributes for the Lamprey River Designated Reach are displayed in bold text.

River	Agency	Site I.D.	Stream Order	Drainage Area	Average Elevation	Gradient	% Calcareous Geology	Level III EcoRegion
Lamprey River	**NA**	**NA**	**4**	**160**	**15.4**	**0.001**	**33.4**	**59**
Cocheco River	NHDES	98P-50	4	49	74.5	0.0019	0	59
Cocheco River	NHDES	98P-51	4	59	68	0	0	59
Cocheco River	NHDES	00P-45	4	64	61	0.0024	0	59
Cocheco River	NHDES	98P-52	4	95	37.5	0.0014	1	59
Eightmile River	NEIHP	8	4	46	13.5	0.0022	0	59
Eightmile River	NEIHP	10	4	56	7	0.0047	0	59
Eightmile River	NEIHP	10	4	56	7	0.0047	0	59
Fort River	MADFW	443	4	43	38.5	0.0014	0	59
Fort River	MADFW	442	4	37	45	0.002	0	59
Isinglass River	NHFGD	ST027	4	41	77.5	0.0061	0	59
Isinglass River	NHDES	98P-54, 98P-54-06	4	57	53	0.0027	2	59
Isinglass River	NHDES	98P-53	4	64	36.5	0.0031	4	59
Nissitissit River	MADFW	1087	4	52	63	0	19	59
Nissitissit River	MADFW	1089, 1090	4	60	58	0.0028	30	59
Wood River	RIDFW	4, 2, 32	4	75	21	0.0011	0	59

Lamprey River Target Fish Community

The TFC for the Lamprey River consisted of a diverse fish fauna of 18 species, dominated by common shiner (31%), fallfish (16%), American eel (10%), common white sucker (8%), longnose dace (6%), and redbreast sunfish (5%). The remaining 11 species comprised between 1% and 4% of the fauna, and included pumpkinseed, blacknose dace, chain pickerel, Atlantic salmon, yellow perch, brown bullhead, creek chubsucker, redfin pickerel, bridle shiner, brook trout, creek chub, and swamp darter. A chart of the TFC species and their expected proportions is shown in **Figure 2**. The Lamprey TFC consisted of 31% fluvial specialist, 39% fluvial dependent, and 30% macrohabitat generalist species (**Figure 3**).

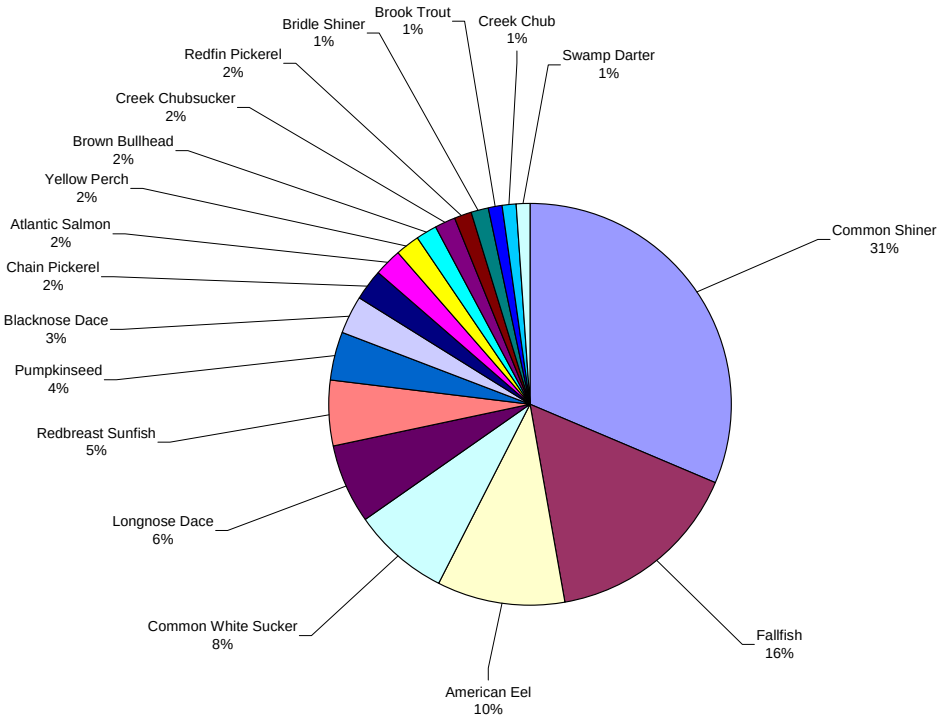

Figure 2. Lamprey River Designated Reach TFC

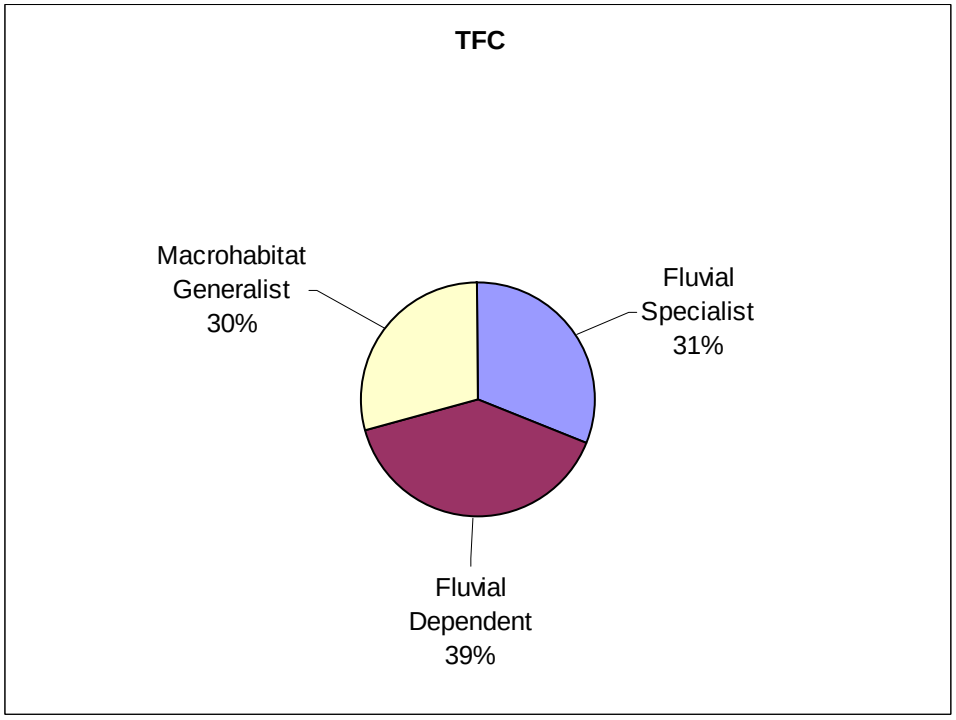

Figure 3. Lamprey River Designated Reach TFC habitat use guilds

Lamprey River Existing Fish Community

The existing fish community of the Lamprey River, as sampled in 2003, consisted of common shiner (33%), redbreast sunfish (14%), fallfish (12%), pumpkinseed (6%), bluegill (6%), common white sucker (5%), American eel (5%), longnose dace (5%), golden shiner (4%), smallmouth bass (2%), largemouth bass (2%), yellow perch (1%), bridle shiner (1%), yellow bullhead (1%), chain pickerel (1%), and 11 other species comprising the remaining 2% of the community (**Figure 4**). The Lamprey River existing fish community consisted of 18% fluvial specialists, 40% fluvial dependent, and 42% macrohabitat generalists (**Figure 5**). A total of 26 different fish species were sampled from the Lamprey River, 18 of which were native. Eight non-native fish species, bluegill, black crappie, brown trout, largemouth bass, rainbow trout, rock bass, smallmouth bass, and yellow bullhead were sampled and accounted for a combined 11% of the community.

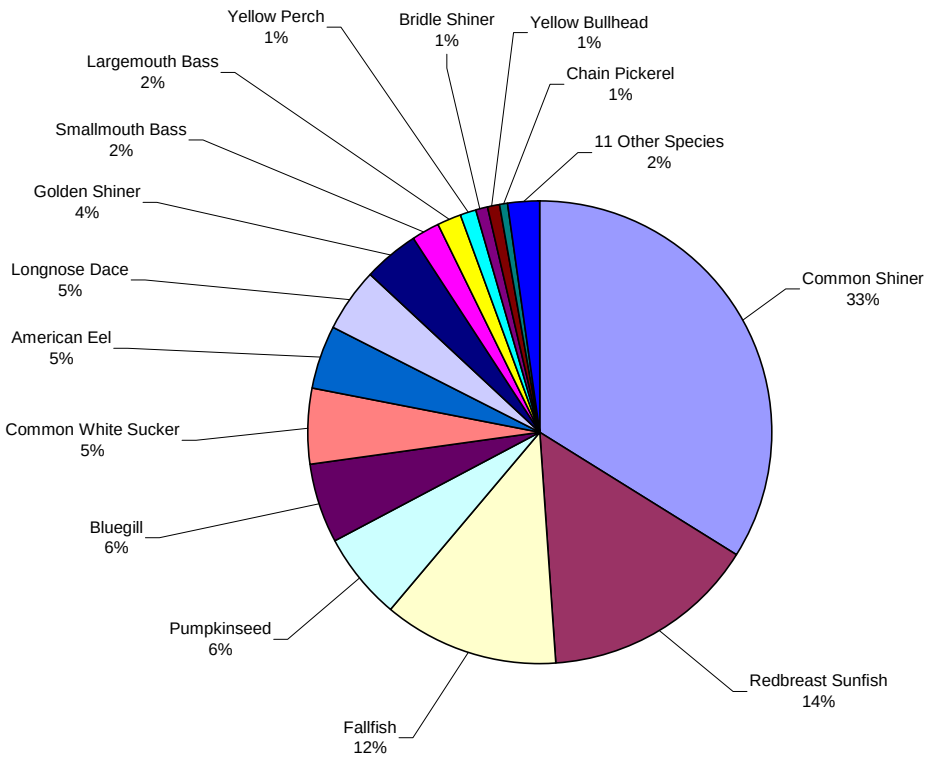

Figure 4. Lamprey River Existing Fish Community

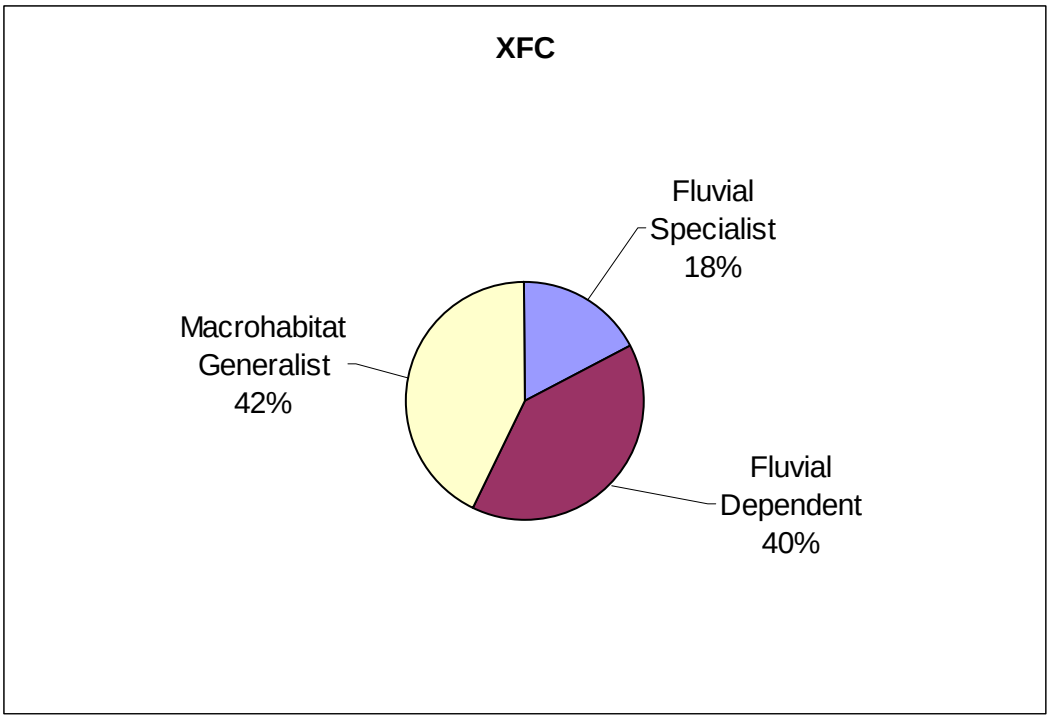

Figure 5. Lamprey River Existing Fish Community Habitat Use Guilds

Fish Community Evaluation

The overall affinity of the existing fish community to the TFC model was 71%. Comparison of the existing fish community and TFC based on habitat use guilds showed a close match between the two communities (**Figure 6**). Differences are apparent in a slight overabundance of macrohabitat generalist species and an underabundance of fluvial specialist. These differences however are minor. Specific proportions of these guilds within the communities were given previously in the sections describing the TFC and existing fish community, respectively and can be viewed within Figure 6. The percent model affinity similarity calculation for the two communities based on species habitat use classifications yielded a value of 86% similarity.

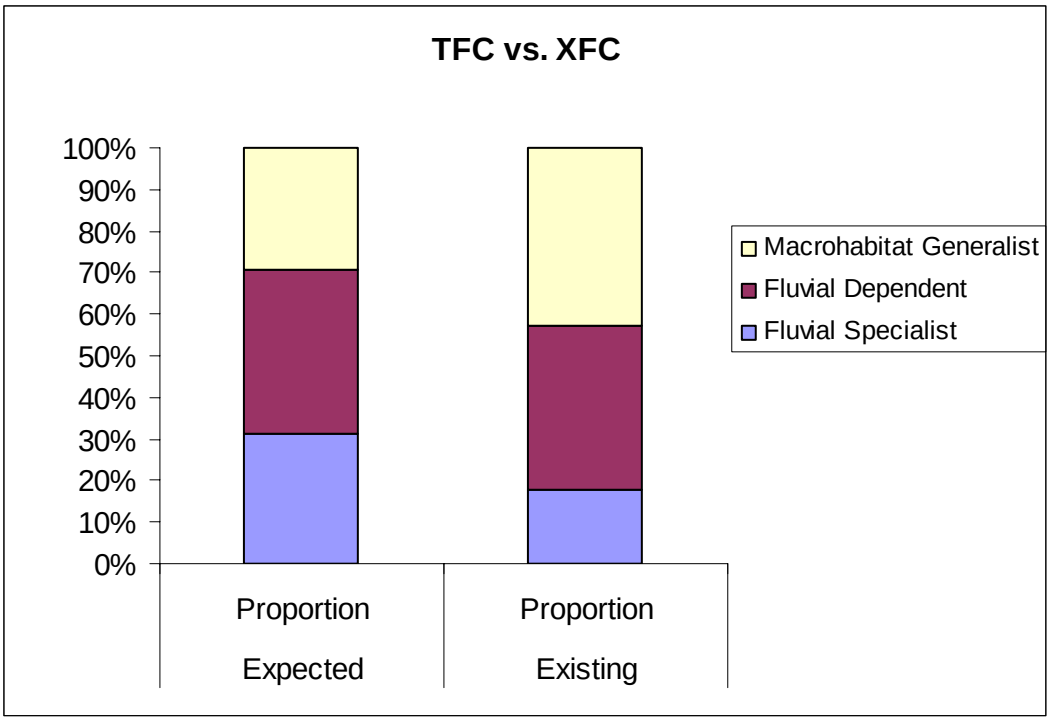

Figure 6. Comparison of the Lamprey TFC and existing fish communities based on habitat use classification guilds

The comparison of the proportions of fish species pollution tolerance classification guilds of the existing fish community (20% tolerant, 79% moderately tolerant, and 1% intolerant species) to those of the TFC (24% tolerant, 70% moderately tolerant, and 6% intolerant species) showed a considerable under-representation of pollution intolerant species within the existing fish community. Differences between pollution tolerant and moderately tolerant species, however, were minor (**Figure 7**). Overall, the communities scored a 91% model affinity value based on the similarity between the proportions of pollution tolerance guilds within each community.

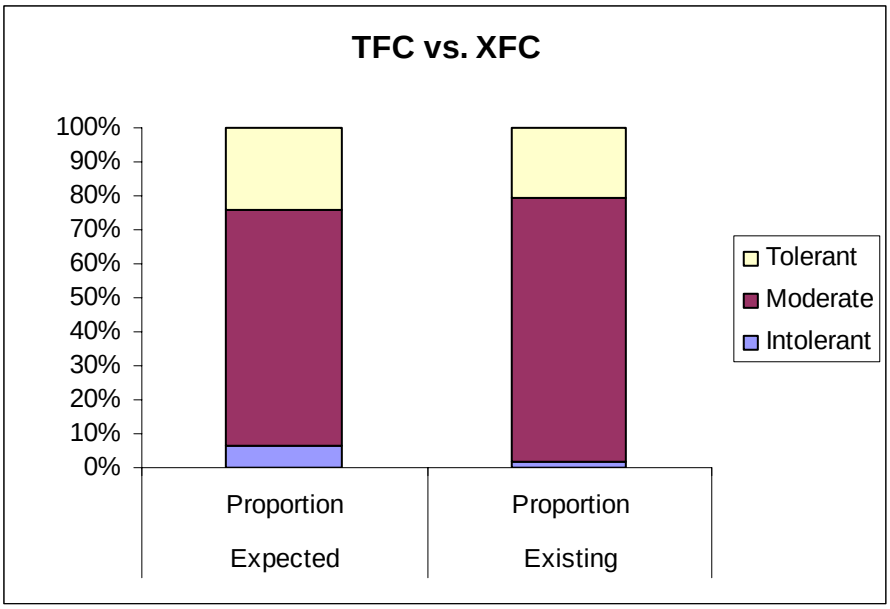

Figure 7. Comparison of the Lamprey TFC and existing fish communities based on pollution tolerance classification guilds

When the TFC and existing fish community were compared based on the proportions of fish species thermal regime tolerance guilds, considerable differences were observed (**Figure 8**). The existing fish community consisted of 31% warm, 69% eurythermal, and 0.2% cold-water fish species. While eurythermal fish species existed in a proportion somewhat similar to the expected proportion of the TFC (80%), proportions of warm species were considerable higher than the expected proportion of 17%, and cold-water species were dramatically lower than the expected proportion of 3%. When a percent model affinity similarity measurement was applied to the existing fish community and TFC pollution tolerance guild proportions a value of 86% was calculated.

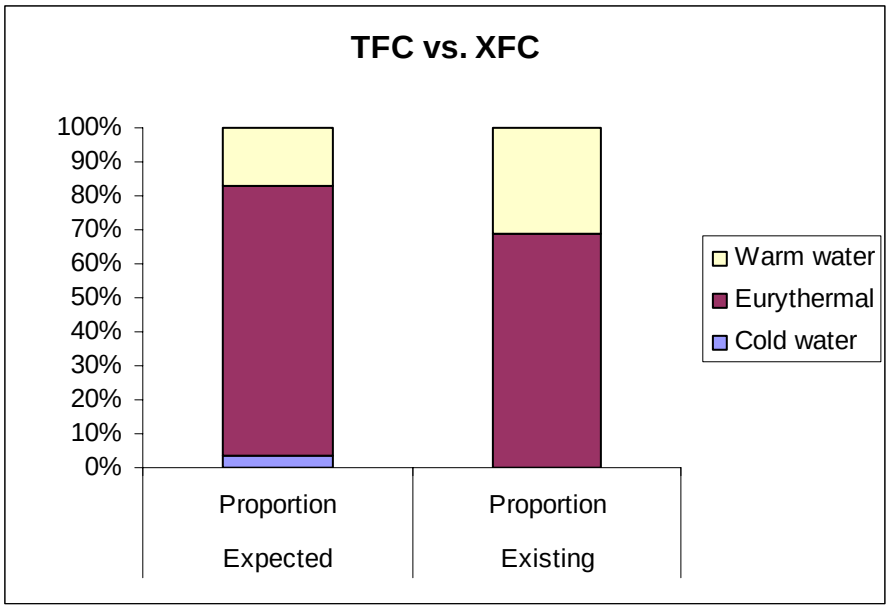

Figure 8. Comparison of the Lamprey TFC and existing fish communities based on thermal regime classification guilds

In the Lamprey River there were seven individual native species that were considered as under-represented and two that were considered overly abundant. Six species were recorded in proportions similar to those expected by the TFC, while three species were absent. There were eight non-native fish species found to occur within the Designated Reach. Non-native species are not a part of the TFC and these species are considered over abundant within the Lamprey River as a result. There was one native species sampled within the Lamprey River which was not included within the TFC. Individual fish species are listed in **Table 3** based on their designations as under-represented, overly abundant, missing, introduced, or occurring as expected within the Lamprey River. Anadromous species expected to occur within the Lamprey River are also identified. Two out of the seven diadromous species expected to occur within the Lamprey River were sampled within the existing fish community.

Table 3. Comparison of proportions of fish species between the TFC and the Lamprey River Designated Reach existing fish community identifying under-represented, existing as expected, overly abundant, missing, and introduced species in the Pomperaug River. Native (N) or introduced (I) statuses, fluvial specialist (FS), fluvial dependent (FD), or macrohabitat generalist (MG) habitat use classifications, intolerant (I), moderate (M), or tolerant (T) pollution tolerance classifications, and Cold, Cool, or Warm water thermal regime classifications are given for each species. Anadromous species expected to occur during seasonal migration periods or fresh water life-history bio-periods are also identified.

Species	Proportion of Target Fish Community	Proportion of Existing Fish Community	Percent Deviation	Native or Introduced	Habitat use Classification	Pollution Tolerance	Thermal Regime
Underrepresented fish species							
American Eel[1]	10%	5%	56%	N	MG/FD*	T	Eurythermal
Blacknose Dace	3%	0.3%	90%	N	FS	T	Eurythermal
Chain Pickerel	2%	1%	75%	N	MG	M	Warm
Atlantic Salmon[1]	2%	0.2%	91%	N	FS	I	Cold
Brown Bullhead	2%	0.2%	90%	N	MG	T	Warm
Creek Chubsucker	2%	0.3%	78%	N	FS	I	Eurythermal
Redfin Pickerel	1%	0.1%	94%	N	MG	M	Warm
Fish species recorded as expected							
Common Shiner	31%	34%	9%	N	FD	M	Eurythermal
Fallfish	16%	12%	22%	N	FS	M	Eurythermal
Common White Sucker	8%	5%	34%	N	FD	T	Eurythermal
Longnose Dace	6%	5%	27%	N	FS	M	Eurythermal
Yellow Perch	2%	1%	33%	N	MG	M	Eurythermal
Bridle Shiner	1%	1%	34%	N	MG	I	Warm
Overly abundant fish species							
Redbreast Sunfish	5%	15%	190%	N	MG	M	Warm
Pumpkinseed	4%	6%	54%	N	MG	M	Warm
Missing fish species							
Brook Trout	1%	-	100%	N	FS	I	Cold
Creek Chub	1%	-	100%	N	FS	T	Eurythermal
Swamp Darter	1%	-	100%	N	MG	M	Warm
Introduced species present within the existing fish community (considered overly abundant)							
Bluegill	-	6%	N/A	I	MG	T	Warm
Smallmouth Bass	-	2%	N/A	I	MG	M	Eurythermal
Largemouth Bass	-	2%	N/A	I	MG	M	Warm
Yellow Bullhead	-	1%	N/A	I	MG	T	Warm
Black Crappie	-	0.3%	N/A	I	MG	M	Warm
Rock Bass	-	0.3%	N/A	I	MG	M	Eurythermal
Brown Trout	-	0.05%	N/A	I	FD	I	Cold
Rainbow Trout	-	0.02%	N/A	I	FD	I	Cold
Native fish species currently or historically present within the Lamprey River missing from the Target Fish Community							
Golden Shiner	-	4%	N/A	N	MG	T	Eurythermal
Anadromous species expected to be present within the Lamprey River during seasonal spawning migration and freshwater life-stage bio-periods							
Alewife[1] [2]	Expected	Present	N/A	N	FD	M	Eurythermal
Blueback Herring[1] [2]	Expected	Present	N/A	N	FD	M	Warm
American Shad[1] [2]	Expected	Not Sampled	N/A	N	FD	M	Warm
Sea Lamprey (adult)[1] [2]	Expected	Not Sampled	N/A	N	FD	M	Eurythermal
Sea Lamprey (ammocoete)[1]	Expected	Not Sampled	N/A	N	FD	M	Eurythermal
Rainbow Smelt[1] [2]	Expected	Not Sampled	N/A	N	FD	M	Cold

[1] Diadromous species

[2] Anadromous pulse species (non-resident)

Discussion

The TFC model presented here provided us with the minimal amount of information deemed necessary to evaluate the existing fish community of the Lamprey River Designated Reach. The computational framework of the TFC model accounted for spatial and temporal variations as well as potentially missing or under-represented fish species within individual Reference Rivers and created a robust representation of the expected native fish community of the Designated Reach. Multi-scale comparisons between the TFC model and the existing fish community allowed us to identify deviations from reference conditions (TFC) and to infer potential reasons for such deviations as they may relate to instream habitat and flow conditions, water quality, or thermal regime providing us with an indication of the biological integrity of river.

The initial list of fish species with known current or historic distributions within the Lamprey River Watershed was established through reviews of Carpenter and Siegler's *Fishes of New Hampshire* (1947) and Scarola's, *Freshwater Fishes of New Hampshire* (1987), and recent Lamprey River Watershed fish survey data (NHFGD, NHDES). Further review of Schmidt's, *Zoogeography of the Northern Appalachians* (1986) provided additional information on regional zoographic distributions of species and supplemented the initial list. This comprehensive list was then reviewed by local fisheries biologists familiar with the fish fauna of the Lamprey Watershed, and species were added or removed accordingly. As a result, burbot *Lota lota*, central mudminnow *Umbra limi*, longnose sucker *catostomus catostomus*, margined madtom *Noturus insignis*, northern pike *Esox lucius*, and walleye *Stizostedium vitreum* were removed from the list.

Diadromous species were included in this list due to the importance of maintaining and restoring populations of these fish within the state of New Hampshire and particularly within the Lamprey River Watershed (TNC 2006). Alewife, American eel, Atlantic salmon, and blueback herring currently exist within the Lamprey River and, hence, were included without controversy (NHDES 2005). It was determined that the historical distributions of American shad, rainbow smelt, and sea lamprey within New Hampshire included the Lamprey Watershed (Jackson 1922, TNC 2006). Therefore,

these species were also included in the list. The final list contained a wide range of species and families that are indicative of the fish fauna of the Northeastern Coastal Zone ecoregion and provided a feasible and comprehensive summary of the current, historic, or potential fish fauna of the Lamprey River Watershed.

The major difficulty of this analysis was in the selection of suitable Reference Rivers. Finding enough low impact Reference Rivers to provide adequate fish data for calculation of the TFC was problematic due to the fact that low gradient, coastal, fourth-order streams are often associated with human land-use alterations (e.g. dams, residential development). Many potential Reference Rivers of the Lamprey River exhibited such impacts and could not be used. As a result of the lack of suitable References Rivers, two rivers that were affected by such impacts and would not have otherwise been considered as Reference Rivers, the Cocheco and Isinglass Rivers were considered. An analysis of the fish data from these rivers revealed fish assemblages that contained species which were appropriate for the Lamprey TFC and were not indicative of impacted habitat conditions. It was also realized that the inclusion of these two rivers would account for two important fish species, bridle shiner and swamp darter that would not have been accounted for in a TFC developed without these two rivers. Therefore, the Cocheco and Isinglass Rivers were included as Reference Rivers and fish data from these rivers were used in the development of the TFC. Given the circumstances it was deemed reasonable, justifiable, and necessary to include these rivers and their fish data in the development of the TFC. The final TFC developed for the Lamprey River was a robust and complete composition of the species expected to occur within lowland, coastal, fourth order streams and included many species unique to this macrohabitat type, namely, bridle shiner, redfin pickerel, and swamp darter. The only species missing from the TFC that should be accounted for is banded sunfish. The patchy and limited distribution of this species make it a species of conservation concern within the state of New Hampshire and explains the difficulty in accounting for this species from reference river data. This fish has been recorded within the Lamprey River in the past, although it was not collected during the Lamprey River Baseline Fish Community Sampling (Carroll 1996, NHFGD 1983-1985).

Prior to the development of the TFC model it was concluded that diadromous fish species were an important component of the Lamprey River's current and historic fish community and should be considered when creating a TFC. Among, the historically present species considered, it was decided that specific proportions would not be specified within the TFC for alewife, American shad, blueback herring and rainbow smelt due to the fact that these anadromous species are only present within rivers for a short period of time during migratory pulses or their juvenile life stages. Proportions of another anadromous species, sea lamprey, were also not specified within the TFC due to this species habitat-use behavior during its freshwater juvenile life-stages. Given that this species burrows into the sediment and filter-feeds from this stationary position, in a fashion more similar to a freshwater mussel than a fish, sampling of this species can be difficult resulting in limited or inaccurate data and making the identification of appropriate proportions of these species within a TFC difficult. For these reasons these species were treated separately within the Lamprey TFC. While specific proportions were not specified for these species, they were designated as expected to be present. The inclusion Atlantic salmon and American eel within the Lamprey TFC was determined to be necessary to consider the habitat and flow needs of these two species. The facts both of these species are present within the river year-round, spend multiple years of their life history cycle within freshwater, and are currently present within the Designated Reach resulted in our decision to include them within the TFC. The New Hampshire Fish and Game Department considers the Lamprey River one of the most important rivers within the state of New Hampshire for diadromous fish.

A multi-level comparison between the TFC model and the existing fish community which was conducted at both the individual species-specific level and the species-group level, allowed for a more complete assessment of the existing fish community than an a single level comparison would have. A comparison of species specific differences alone may have been affected by the natural variation of species compositions between the Reference Rivers, while a more generalized comparison of species classification guilds, when considered alone, would not have specified missing, under-represented, over-abundant, or non-native species within the existing fish communities. An evaluation of the existing fish community, which took into

consideration comparisons between TFC model and the existing fish community at both the species specific *and* species guild levels accounted for the deficiencies that either single comparison would have exhibited. These comparisons at multiple levels provided the full range of information required to make logical inferences of potential reasons for differences between the TFC model and the existing fish community. When both comparisons between specific species and guilds of species groups were considered together, an evaluation of the status of a fish community could be more accurately assessed than if either comparison were considered alone.

Overall, the Lamprey River exhibits a relatively healthy fish community dominated by fluvial species. However, this analysis illustrated the impacts that non-native fish species may be having on native stream fish communities and particularly on the native macrohabitat generalists of the Lamprey River. There is considerable evidence to suggest that the impounded areas of the Lamprey River are having a substantial impact on the fish community composition of the Designated Reach. The impoundments alone accounted for an enormous proportion of the non-native fish sampled within the entire river. Investigating this matter further may be critical to the preservation of native fish communities. In particular the fish communities of the Lamprey River should be monitored with regard to this theory to assess the changes in fish community composition over time and in an effort to maintain native fish communities.

Based on their composition within the TFC model, American eel, common shiner, common shiner, common white sucker, fallfish, longnose dace, and redbreast sunfish were selected as indicator species for the MesoHABSIM modeling process. Atlantic salmon and brook trout will also be included as indicator fish species due to there specific habitat requirements and conservation concern. The habitat suitability requirements (based on linear regression coefficients developed from empirical fish capture data) and weighted proportions of these species within the TFC model will be used to train the Lamprey River MesoHABSIM model.

In addition to providing the indicator species used for habitat modeling, the TFC model served as an evaluation tool for the assessment and evaluation of the Lamprey River existing fish community. An inference approach, based on comparisons between fish species habitat use, pollution tolerance, and thermal regime guilds, as previously

described and discussed was used to identify potential causes for deviations of fish species-proportions from those specified within the TFC model. This analysis and report provide a gauge to guide watershed management objectives and measure the results of any physical or biological rehabilitation efforts that may occur within the Designated Reach of the Lamprey River.

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